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EFFECT OF DEPTH OF SOWING AND WATERLOGGING CONDITIONS ON COTTON SEED GERMINATION

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Abstract

The results on depths of sowing revealed that germination percentage reduced from 91.5 to 76.5, by 7.5 cm depth of sowing as compared to the control (2.5 cm depth). In waterlogged conditions (36 hours), germination percentage reduced from 61.5 to 51.5 by 7.5 cm depth of sowing as compared to the control (2.5 cm depth). However, which were enhanced by application of FYM @1 /ha from 76.5 to 81.5 under no water logging and 51.5 to 53.5 % under water logging conditions

The results found that extended water logging resulted in reduction of the germination percentage of cotton progressively. The absolute control registered 63 % of germination and reduced to 10 % with 72 hours of water logging. The organic amendments used for the seed bed preparation include vermicompost and FYM applied @ 1 t/ha helped to increase germination percentage from 63 to 83.0 for both the amendments under no water logging condition. The application of vermicompost and FYM @ 1 t/ha helped to increase the germination percentage from 10 to 23.0. and 10 to 13.0, respectively, under waterlogged (72 hours) conditions.

The study on the effect of waterlogging on germination percentage (%) of different cotton species revealed that diploids are more sensitive than tetraploids

Key words: Cotton, depth of sowing, farm yard manure, germination, vermicompost, waterlogging.

INTRODUCTION

Cotton, being a major cash crop grown commercially in India, contributes more to the textile industry. It provides a basic raw material for the textile industry. It is the most widespread profitable non-food crop grown in the world. In the global cotton-growing area, India occupies

about 40%. The continuous wet spell during sowing time results in waterlogging conditions and leading to poor drainage and poor germination. These weather aberrations are unpredictable and have increased in the recent past.



Cotton is poorly adapted to waterlogging circumstances (Hodgson and Chan, 1982), which is considered to be one of the major constraints in production (Gillham *et al.*, 1995). One of the main factors needed for seed germination is oxygen, which gets dissolved in water and enters the seed embryo through the micropyle or seed coat. Oxygen initiates aerobic respiration in the seed embryo and encourages germination (Bewley, 1997). At the early germination stage (imbibition), the rate of oxygen absorption in the seed embryo will

be low, but slightly increases during mRNA transcription and is high towards the end of the germination phase. The radicle and plumule protrusion indicate the end of the germination phase. When there is an absence (anoxia) or a limited amount of oxygen (hypoxia) entering the seed, the seeds may fail to germinate.

Vermicompost is an organic manure produced from earthworms. It helps in improving soil texture, aeration, and upsurges water retention capacity, and also

acts as a soil conditioner. It improves the biological, physical, and chemical properties of soil and helps in seed germination under waterlogged conditions. Farmyard manure improves the soil water water-holding capacity and also increases the microbial activity to supply nutrients

for germination and growth. Application of organic amendments, viz., vermicompost and farm yard manure to the soil under waterlogged conditions improves the seed germination and growth.

MATERIALS AND METHODS



A pot experiments were conducted at Central Institute of Cotton Research, Regional station, Coimbatore in the year of 2022-23 and 2023-24 to evaluate the germination percentage of cotton seeds with different depth of sowing, exposure of the seeds to different hours of waterlogging conditions with application of organic amendment (farmyard manure) and also evaluated the germination percentage of different cotton species under waterlogged condition (36 hours).

To optimize the depth of sowing, the cotton seeds were sown at different depths, viz., 2.5, 5.0, and 7.5 cm, with and without farm yard manure, superimposed with water logging and control

To evaluate the effect of organic amendments on seed germination, cotton seeds were exposed to different hours of waterlogging conditions, viz., 24, 36, 48, 60, and 72 hours, with control and organic amendments, viz., vermicompost and farm

yard manure @1 ton/ ha were applied for seed bed preparation.

To evaluate the effect of waterlogging conditions on germination of different species of cotton, viz., *Gossypium arboreum* (PA 528), *Gossypium barbadense* (Suvin), *Gossypium hirsutum* (Suraj), *Gossypium herbaceum* (G Cot 25), H x H (RCH 659 BG II), and H x B(MRC 7918 BG II), were tested. The twenty seeds were exposed to 36 hours of

waterlogged conditions with a control. The germination percentage was evaluated as the number of seeds germinated from the seeds sown.

RESULTS AND DISCUSSION

Effect of depth of sowing and amendments used for seed bed preparation on germination of cotton seeds under waterlogging (pot culture)



The results of the experiment on different depths of sowing of cotton with and without water logging found that the depth of sowing increased from 2.5 cm to 7.5 cm, resulting in reduced germination percentage in both situations. The germination percentage reduced from 91.5 to 76.5, respectively, for 2.5 and 7.5 cm depth of sowing under control. In waterlogged conditions (36 hours), germination percentage reduced from 61.5

to 51.5, respectively, for 2.5 and 7.5 cm depth of sowing. Germination was affected negatively by an increase in sowing depth and duration of waterlogging conditions. The higher rate of germination failure was observed with the combination of higher soil depth and waterlogging conditions. The highest reduction percentage of 51.5 per cent was recorded with sowing of seeds in 7.5 cm depth with water logging (36 hours) as compared to 91.5 per cent

recorded with sowing of normal depth (2.5 cm) without water logging (Table 1 & fig. 1)

The experimental results further revealed that the addition of farm yard manure @1 t/ha in preparation of the seed bed enhanced germination percentage of seeds sown in higher soil depth and water logging conditions as compared to the control (No FYM application). Sowing of seeds in 7.5 cm soil depth registered a germination percentage of 76.5, which was enhanced by application of FYM @1 /ha (81.5 %). The germination percentage of 51.5 per cent was recorded with 7.5 cm depth with continuous water logging (36 hours); which was enhanced to 53.5 by adding FYM @ 1.0/ha with this combination.



Waterlogging and higher depth of sowing resulted in poor germination. This may be due to the unbreakability of the soil by the seeds to germinate and the unavailability

of oxygen for respiration (waterlogged condition). This decrease in germination ability is attributed to a deficiency of oxygen due to waterlogging conditions (Orchard and Jessop, 1984). During germination, when oxygen is scarce, respiration and electron transport are inhibited and ATP formation is diminished (Al-Ani *et al.*, 1985; Johnson *et al.*, 1989; Tsai *et al.*, 1997). Similar results were accordance with Anjah Mendi Grace and Christiana Ngyete Nyikob Mbogue (2020) in *Aframomum citratum* seeds and Nabi *et al.*, (2001) in cotton seeds. Application of farmyard manure in the seedbed helps to increase the mean germination percentage, respectively with control and waterlogging (36 hours) conditions . Farm yard manure application under waterlogged conditions helps in improving the soil structure by holding the excess water and supplying aeration to the soil, which paved the way for cotton seed germination. It also increases the microbial activity and helps in supplying nutrients for germination.

Effect of duration on water logging and amendments used for seed bed preparation on germination percentage (pot culture)

The results of water logging experiment with respect to duration of water logging and amendments used for seed bed preparation found that extended water logging resulted in reduction of the germination percentage of cotton progressively. The absolute control registered 63 % of germination and reduced to 10 % with 72 hours of water logging (Table 2 & fig. 2) . Waterlogging conditions resulted in lower germination of cotton seeds. This is mainly due to oxygen

deficiency, hypoxia, or anoxia. When hypoxia conditions occur, oxygen content of the soil gets reduced to below the optimal level, which results in lower germination of seeds. Anoxia usually refers to complete oxygen deprivation (Hossain and Uddin, 2011). Anoxia is always preceded by hypoxia in waterlogged environments (Setter T. L., Waters I., 2003; and M. C. Drew, 1997). Similar outcomes were reported in barley by Arduini *et al.* (2016).

The organic amendments used for the seed bed include vermicompost and FYM applied @ 1 t/ha helped to increase germination percentage from 63 to 83.0 and 83.0 per cent, respectively, under no water logging condition (Control). However, under 72 hours of water logging, application of vermicompost and FYM @ 1 t/ha helped to increase the germination percentage from 10 to 23.0. and 10 to 13.0 respectively. This increase in germination percentage by vermicompost is might be due to the aeration supply by absorbing the excess water. Moreover, it has high porosity, water holding capacity, and supplies nutrients for germination (Hoque *et al.*, 2022).

Effect of waterlogging on germination percentage (%) of different cotton species (pot culture)

The study on effect of waterlogging on germination percentage (%) of different cotton species revealed that water logging (36 hours) reduced the germination percentage of 40.5, 35.0, 21.0, 37.6, 24.5, and 26.3 respectively with *Gossypium arboreum* (PA 528), *Gossypium barbadense* (Suvin), *Gossypium hirsutum* (Suraj), *Gossypium herbaceum* (G Cot 25), H x H (RCH 659 BG II) and H x B

(MRC 7918 BG II) (Table 3). The results further revealed that diploids are more sensitive (*Gossypium arboreum* (PA 528) and *Gossypium herbaceum* (G Cot 25)) than tetraploids (*Gossypium barbadense* (Suvin), *Gossypium hirsutum* (Suraj)), H x H (RCH 659 BG II) and H x B (MRC 7918 BG II). Under waterlogged conditions, there will be a rapid decline in dissolved oxygen concentration in the soil water, which results in failure of seed germination and lengthening of the germination time (Perez-Ramos and Maranon 2009).

CONCLUSION

The study revealed that the depth of sowing and extent of water logging positively correlated reduction in germination percentage. Soil bed preparation with FYM/ vermicompost could enhance the germination percentage both under control and waterlogging conditions. The application of vermicompost @1t/ha for seed bed preparation helped to increase the germination of cotton seeds irrespective of different depths of sowing and different durations of exposure to waterlogged conditions. The study on the effect of waterlogging on germination percentage (%) of different cotton species revealed that diploids are more sensitive than tetraploids

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Table 1. Germination percentage (%) as influenced by depth of sowing and organic amendments used for seed bed preparation under water logging

Depth of sowing	Control	Water logging (36 hrs)
T ₁ - 2.5cm (soil)	91.5	61.5
T ₂ -5cm (soil)	88.5	58.5
T ₃ -7.5cm (soil)	76.5	51.5
T ₄ -2.5cm (soil +FYM)	95.0	68.5
T ₅ - 5cm (soil +FYM)	93.5	63.5
T ₆ -7.5cm (soil +FYM)	81.5	53.5

Table 2. Germination percentage as influenced by organic amendments used for seed bed preparation

Treatments	Soil	Soil with vermicompost	Soil with FYM
T1.Control	63.0	83.0	83.0
T2.24 hours	33.0	53.0	43.0
T3.36 hours	23.0	47.0	27.0
T4.48 hours	17.0	33.0	23.0
T5.60 hours	13.0	23.0	13.0
T6.72 hours	10.0	23.0	13.0

Table 3. Germination percentage (%) of different cotton species under waterlogging

Treatments	Control (20 seeds)	water logging (36 Hours) (20 seeds)	Reduction of Germination (%) by waterlogging
T1. <i>Gossypium arboreum</i> (PA 528)	17.3	10.3	40.5
T2. <i>Gossypium barbadense</i> (Suvini)	14.3	9.3	35.0
T3. <i>Gossypium hirsutum</i> (Suraj)	14.3	11.3	21.0
T4. <i>Gossypium herbaceum</i> (G Cot 25)	13.3	8.3	37.6
T5.HxH (RCH 659 BG II)	16.3	12.3	24.5
T6.HX B(MRC 7918 BG II)	16.7	12.3	26.3

Fig 1. Germination Percentage (%) as influenced by depth of sowing, water logging and FYM application

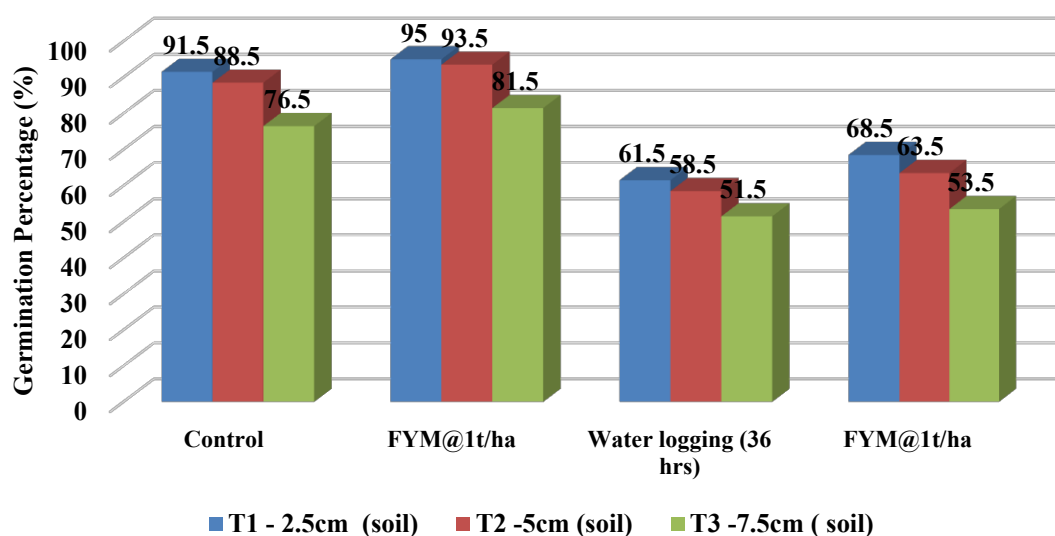
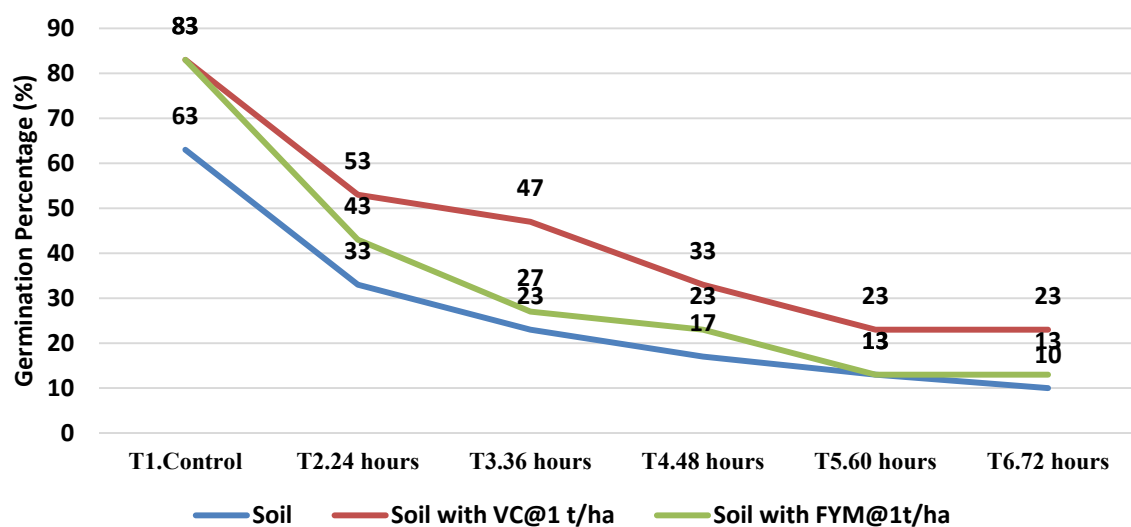


Fig 2. Germination Percentage as influenced by extent of water logging with and without FYM/VC @1 t/ha)



CUSTOMIZED FERTILIZER – A THOUGHT FOR SUSTAINABLE COTTON PRODUCTION

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Introduction

Cotton is an important cash crop but it is considered as a nutrient depleting crop due to high biomass accumulation and rapid nutrient uptake rate. Moreover, nutrient management for cotton is a complex phenomenon due to simultaneous production of vegetative and reproductive parts during their active growth phases. At this juncture, injudicious or imbalanced application of fertilizers *i.e.*, over and under fertilization impairs the potential yielding capability of cotton, accelerating multi nutrient deficiencies in soils and rising the issues of environmental pollution. Continuous application of blanket fertilizer recommendation (RDF) is the main cause for poor fertilizer use efficiency owing to the heterogenetic nature of soil and nutrient mining of other essential nutrients. Moreover, blanket fertilizer recommendation *i.e.*, imbalanced and sub optimal supply of nutrients fails to fulfil the nutrient requirement of the plant. In most of the nutrient management programs, micronutrients like zinc, iron, copper, manganese and boron are not included in or administered in sufficient quantities due to their higher cost and application charges, as well as their timely

inaccessibility during sowing. Hence, multinutrients that are site-, soil-, or crop-specific are essential for improving the efficiency of nutrient utilization by lowering fertilizer losses, balancing the nutrient addition, satisfying the nutrition demand of the crop, realizing the full yield potential thus sustaining the cotton productivity and farm profitability under different soil conditions. Achieving the balanced nutrition in crops is not so facile without modifying the fertilizer product and hence custom made fertilizers *i.e.*, customized fertilizers are identified in recent years.

Customized fertilizers

Customized fertilizers (CF) are multinutrient carriers that contain macro, secondary and micro-nutrients from both inorganic and/or organic sources to promote the balanced fertilization, provide the site specific nutrient management, fulfill the crop's nutritional demand, maximize the fertilizer use efficiency, minimize the unwanted impacts on the environment and improve the benefit-cost ratio. Customized fertilizer has been accepted by the Central Fertilizer Committee of India as a new type of site/soil/crop specific fertilizer and

included in the Fertilizer Control Order (1985). To formulate the crop or soil specific customized fertilizers, georeferencing the particular fertility management zones / area using GPS would be the first option and second option would be sampling of soil, water and crop to assess the soil fertility rating and crop nutrient requirement. Nutrient optimization for targeted yield of the crop can also be done using empirical models like QUEFTS/STCR/DSSAT and response curve (RC) approach. Different methods like bulk blending, compound granulation/steam granulation, complex/chemical granulation and compaction are used to prepare the customized fertilizers. Now days, customized fertilizers with controlled release in the form of liquid, granules, tablet and pellet is being aimed for effective utilization of nutrients without any wastages, achieving maximum economic yield and excellent farmers profit. Since CF are soil / crop specific, crop response, nutrient use efficiency and better yield are prominently higher than conventional fertilizers.

Customized fertilizers in India

In India, customized fertilizer are formulated specifically for soil and crops based on sound plant nutrition principles by four major fertilizer producing companies like Tata chemical Ltd., Deepak Fertilizers, Nagarjuna fertilizers and Coromandal industries Ltd. 'Paras farmoola' by Tata Chemicals Ltd (TCL) was the first one to produce customized fertilizers in India which are specially designed for farmers in Uttar Pradesh. Till now, 36 formulations of customized fertilizers were approved by Fertilizer Control Order (1985) and 24 grades of CF are developed for crops like rice, wheat,

sugarcane, potato and mint. The newly developed customized fertilizers properties should strictly adhere to the specifications given by FCO and duly approved by ministry for further commercialization.

Effects of customized fertilizers on crops

Customized fertilizers developed by Tata chemicals Ltd. was evaluated in Noida on various crops and found to exhibit 14, 20, 15 and 40 per cent of increased yield in rice, wheat, potato, and sugarcane respectively over the common farmer's practice (Singh et al., 2012). Some of the researchers in India prepared the customized fertilizers by simple blending of blanket fertilizers i.e. recommended dose of fertilizer (RDF) and evaluated in various crops. Ramesh et al. (2013) studied the CF on castor-sorghum cropping system and observed better crop growth, increased yield attributing characters and higher nutrient uptake in both the crops. Application of 100% RDF through customized fertilizer registered an increase in rice yield of 22.2% over the application of straight fertilizers (Kaleeswari, 2013). Application of 100 % RDF as CF I + 25 kg ZnSO₄ ha⁻¹ registered an increase in rice yield of 17.7 per cent over the application of straight fertilizers. Dwivedi et al. (2014) reported that application of 150 % dose of CF produced highest grain yield of wheat (4.4 t/ha), which was 28.3 % higher than that of state recommended dose (120:60:40 kg NPK/ha). Kamble and Kathmale (2015) revealed that significantly highest plant height (57.77cm), stem diameter (6.03cm) and bulb diameter (15.13cm) at the time of harvest, fertilizer use efficiency, bulb yield (22.34 t ha⁻¹) and benefit:cost ratio (2.56) of onion were recorded in 100 % recommended dose of NPK through CF in

three equal split doses. Kumar et al., (2017) found the improved quality parameters like head rice recovery (%) and reduce the broken percentage in scented rice due to CF (N, P, K, Zn, B) application. Anju et al., (2020) developed Custom Mixed Fertilizers by using STCR and RC approach for Elephant Foot Yam under Intercropping in Coconut Gardens for Kerala.

Formulation of customized fertilizer for cotton

For cotton, customized fertilizers are formulated by considering the fertility status of the soil through soil and crop response studies in a particular region. Major fertilizer nutrient requirements for cotton were derived and also secondary and micronutrients combinations were added based on the crop performance. Biofertilizer like Azophos was also mixed with the customized fertilizer to improve the fertilizer efficacy. Among the methods of customized fertilizer preparation, compaction method was followed in which fertilizer material were grounded and powdered and then applied pressure to make the powdered form of fertilizer into pelleted form. Pelletization process was standardized by mixing of different types of organic based binding material in different ratios. The newly designed fertilizer pellets are smooth, uniform and glossy surfaced and used for both basal and top dressing application.

Effects of customized fertilizer on cotton production

Field experiment was conducted during the year 2023-24 at ICAR- Central Institute for Cotton Research (ICAR – CICR) to evaluate the newly developed site / soil / crop specific

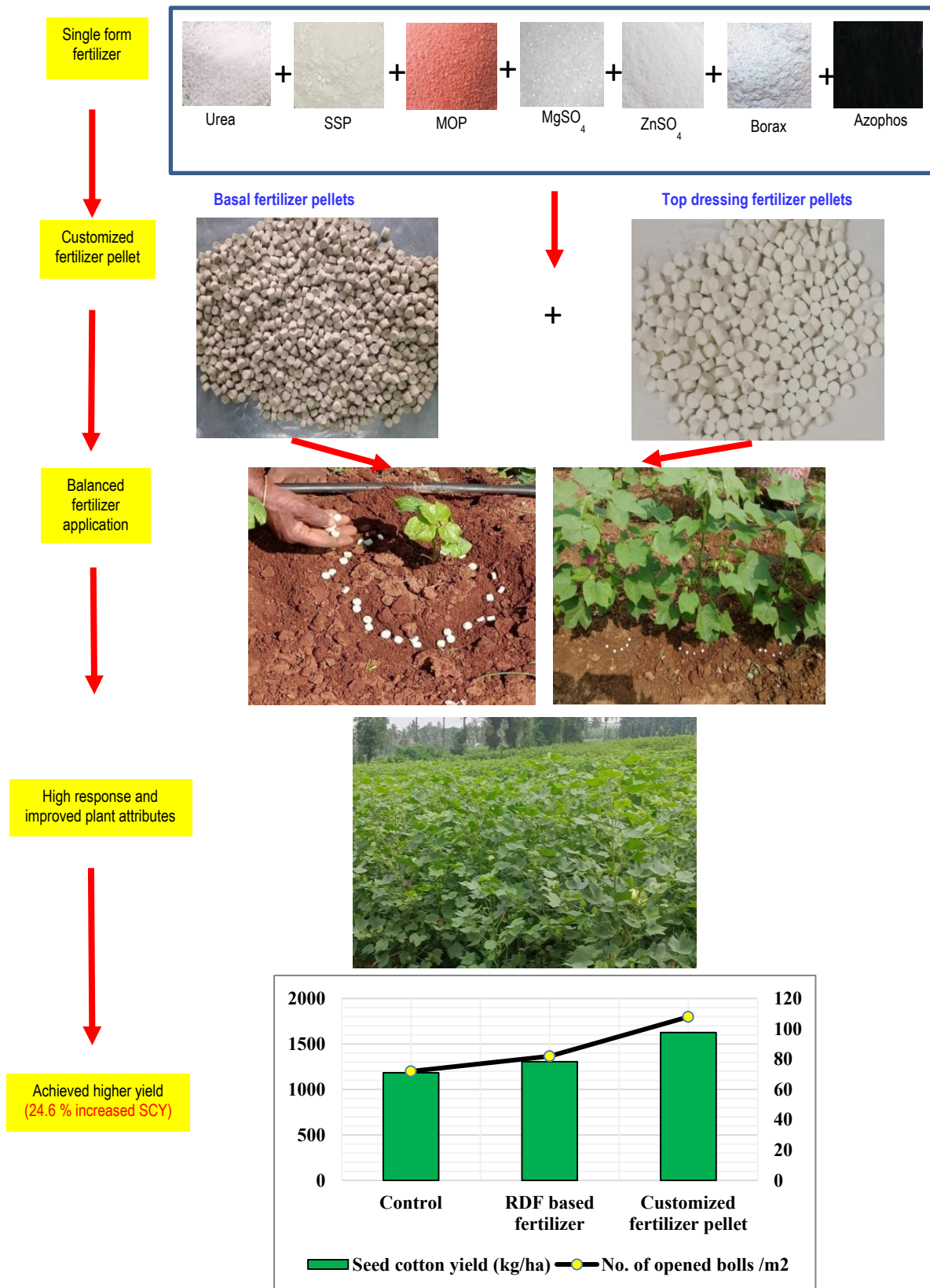
(Periyanaickenpalayam soil series) customized fertilizers on cotton variety suraksha. For basal fertilizer application, combinations of half of N and K, full dose of P and double dose of secondary and micronutrients along with biofertilizer (2 kg/ha) were pelletized and then required quantity of pellets were applied around each plant. The remaining half of N and K were split into two parts and were pelletized for top dressing application. Seed cotton yield was increased by 24.6 per cent due to customized fertilizer pellets than recommended dose of fertilizers.

Benefits of customized fertilizer

1. Application of customized fertilizer is very simple and easy than conventional fertilizer with the ability to provide all the nutrients to satisfy the nutrient requirement of the crop
2. Nutrients can be distributed uniformly in the root zone
3. Combined form of macro, secondary and micro nutrients are in one pellet, thus saving costs on micronutrient fertilizers.
4. Crop yield maximization with better benefit cost ratio was achieved per pellet application
5. Providing the best nutritional package for better plant growth and premium quality output
6. Ensuring balanced fertilization and sustainable cotton cultivation by reducing the nutrient depletion in soil

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***PHAKOPSORA GOSSYPHII* INCITING RUST DISEASE: AN EMERGING CHALLENGE IN SOUTH INDIA'S COTTON REGION**

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Introduction

Cotton (*Gossypium spp.*) is the world's most widely grown fibre crop, supplying approximately 85% of the raw material used in the textile industry. Its primary economic value lies in the fibre, with lint serving as a fundamental input for textile production globally. In India, foliar disease caused by fungi, bacteria, and viruses along with boll rot, have been estimated to cause yield losses of up to 20-30% (Mayee *et al.*, 2007). Cotton rust, caused by *Phakopsora gossypii* (Arth.) Hirat., is prevalent in tropical and subtropical cotton-growing regions. Under favourable environmental conditions, the disease is widespread and can lead to substantial reductions in yield. Rust was observed (0.0 to 24.0 PDI) during boll maturity and bursting stages, in farmers' fields in Tamil Nadu. The disease was reported to reduce the yield of cotton as

much as 24% in Coimbatore (Johnston, 1963).

Puri *et al.* (1998) reported that the disease appeared in the dry season during December-March and was prevalent in Karnataka, Andhra Pradesh and Gujarat. Tropical rust control has been achieved with the use of fungicides, which greatly increase production costs because resistant cotton cultivars are not yet available to growers (Pindikur *et al.*, 2012). The rust disease incidence observed in CICR, Coimbatore ranged from 5.31 % to 52.12 % in various Bt hybrids and varieties. In many of the hybrids, the range of PDI was from 20.12 % to 27.53%. The highest PDI was observed in hybrid RCH659-55.11% and in variety Suraksha-15.34 % with lowest PDI (Anon., 2022).

In recent years, rust disease has gained significance due to its earlier onset and the significant reduction in seed cotton yield it has caused. Although such

severe damage is not consistently observed every season, major outbreaks were recorded between 2009 and 2012 in northern Karnataka, particularly during the crop's reproductive stage. During this period, yield losses were estimated at 21.7%, with the highest disease severity index reaching 32.8% at Dharwad (Monga et al., 2013). The percent disease index (PDI) ranged from 29.1% to 39.8% across various cotton varieties and hybrids in Dharwad, and from 35.0% to 37.0% in Guntur (Anon., 2015). Estimated avoidable yield losses were 21.7% in Bunny Bt and as high as 34.05% in RCH 2 BG II in Andhra Pradesh (Monga et al., 2013; Bhattiprolu, 2015).

Expression of rust symptoms:

Rust symptoms first appear on the lower to middle leaves, typically during the flowering to boll development stages (120-180 days after sowing), especially in the dry months from December to March. Initial signs include light to brown rusty

spots on older leaves, leading to early leaf drop. Uredial sori develop as small (1-3 mm) pinkish-brown lesions that can merge into larger patches. Yellowish-brown uredia form on both sides of the leaves (**Fig. 1 & 2**), with primary uredia deeply embedded in the upper leaf surface and secondary uredia more superficial on the lower surface. On pedicels and branches, the uredia are oval to circular in shape. As the epidermis ruptures, uredospores become exposed. Symptoms also appeared on petioles, stem and boll (**Fig. 3**). The uredia were elongated in shape. There was a decrease in photosynthetic area of leaves due to rust pustules and finally severe defoliation was noticed in the field which resulted in the reduction of cotton yield. Uredospores of *Phakopsora gossypii* are thin-walled, single celled, oval in shape and rusty red or pale brown in colour (**Fig. 4**). Teliospores was not observed in the infected leaves of cotton. Although the disease generally appears later in the crop cycle, it can still affect yields in late-sown or extended irrigated crops. Cool temperatures promote disease development.



Fig 1. Typical symptoms of cotton rust on adaxial and abaxial surfaces



Fig 2. Typical symptoms of cotton rust expressed in Bt lines



Closure view of uredial pustules on leaf



Rust pustules on boll

Fig 3. Symptoms of rust disease on leaves and boll

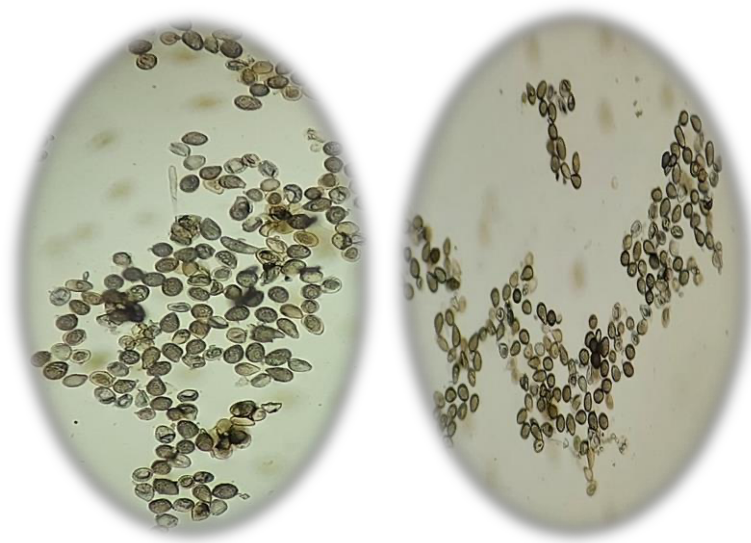


Fig. 4. Uredospores of *Phakopsora gossypii*

Weather variables for the development of disease:

The effect of weather factors on the development of cotton rust in different varieties and Bt cotton hybrids were investigated during kharif 2021-2023 at ICAR- Central Institute for Cotton Research (CICR), Coimbatore under irrigated conditions. Result: The development of rust during different years in the same varieties/hybrids showed similar trend. Correlation analysis of pooled data indicated strong correlations between rust intensity and maximum temperature, wind speed and relative humidity in both varieties and hybrids. Positive and significant correlation of wind speed was recorded both in varieties and hybrids. Multiple regression analysis of pooled data showed that weather parameters including RH I, SSH and windspeed significantly influenced the development of rust disease. In the

hybrids (RCH659 BG II and Suraj Bt) the rust disease intensity starts by 44th meteorological week (*i.e.* first week of November) with 10.8 and 8.8 PDI and attains its peak intensity by 52nd meteorological week (*i.e.* last week of December) with 54.1 and 42.7 PDI respectively. In the varieties (CCH 15 and Suraksha) the disease intensity initiates by 47th meteorological week (*i.e.* third week of November) and reaches its peak intensity by 52nd meteorological week (*i.e.* last week of December) with 27.3 and 15.3 PDI respectively (Valarmathi *et al.*, 2025).

Integrated Management of the disease:

- **Cultural Practices:** Crop Rotation: Rotating cotton with other crops can help reduce the build-up of the rust pathogen in the soil.

- ✓ Sanitation: Removing and destroying infected plant debris can help reduce inoculum levels.
 - ✓ Spacing: Wider row spacing can promote better air circulation and faster drying of the crop canopy, reducing humidity and disease development.
 - ✓ Manage crop residues to minimise carryover of pathogens into subsequent crops
 - ✓ Removal of rust infected leaves to prevent secondary spread of diseases through air borne uredospores.
- **Host Plant Resistance:** Resistant Varieties: Utilizing cotton varieties with inherent resistance to rust is a crucial component of integrated management. This reduces the need for other control methods.
- **Fungicide application:** In the integrated management of the disease, the treatments, hexaconazole - hexaconazole -hexaconazole followed hexaconazole-nimbicide - hexaconazole were found to be effective in managing rust of cotton and increased the yield with maximum benefit cost ratio (Pindikur *et al.*, 2012).
- ✓ The lowest average percent disease intensity (PDI), at 10.7%, was observed when Propiconazole was sprayed at 75, 90, 105, and 120 days after sowing. Yield analysis indicated that applying Propiconazole (0.1%) at 15-day intervals beginning 75 days after sowing up to 120 days helped avoid a yield loss of 34.05%, with a benefit-cost ratio of 1.82.
 - ✓ Pyraclostrobin 20% WG can be used against rust disease in cotton with no phytotoxicity.
 - ✓ Foliar sprays of Copper oxychloride 50 WP @3g or Mancozeb 75 WP @2.5g/l or Propiconazole 25 EC @ 1 ml/l of water as and when symptoms appeared.
 - ✓ The combination fungicides namely Fluxapyroxad 167 g/l + Pyraclostrobin 333g/l SC @ 0.6g/litre of water, Azoxystrobin 18.2% + Difenoconazole 11.4% w/w SC @ 1ml/litre of water, Metiram 55% + Pyraclostrobin 5% WG @ 2g/litre of water, Carbendazim 12% + Mancozeb 63 % WP @ 3g/litre of water showed less rust disease intensity (Anon., 2022).
- **Biological Control:** Neem Products: Neem-based products, like neem cake or neem seed kernel extract (NSKE),

can be used as seed treatments or sprays.

Trichoderma viride: Seed treatment with *Trichoderma viride* along with neem cake has shown promise in reducing mortality and increasing germination.

- **Monitoring:** Regular Plant Inspections: Regularly monitoring plants for early signs of rust is crucial for timely intervention.
- **Hazard Analysis:** Identify potential risk factors and implement appropriate preventative and curative measures.
- By combining these strategies, cotton farmers can effectively manage cotton rust and minimize its impact on yield and quality.

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Content

EFFECT OF DEPTH OF SOWING AND WATERLOGGING CONDITIONS ON COTTON SEED GERMINATION

1

K. Sankaranarayanan, J. Annie Sheeba, P. Valarmathi,
M. Amutha, G. Arun Balaji, V. Anisha and K. Suganya

CUSTOMIZED FERTILIZER – A THOUGHT FOR SUSTAINABLE COTTON PRODUCTION

10

D. Kanjana, R. Raja, S. Usha Rani, J. Annie Sheeba,
Amarpreet Singh and A.H. Prakash

PHAKOPSORA GOSSYPII INCITING RUST DISEASE: AN EMERGING CHALLENGE IN SOUTH INDIA'S COTTON REGION

15

Valarmathi Pandian

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